Atmospheric CH_4 and N_2O from TIR Sensors AIRS/IASI/CrIS

Retrieval, Validation and Monitoring of Trend

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NOAA/NESDIS/STAR

NASA Sounder Science Team Meeting, Greenbelt, Oct.1, 2014

Outline

- AIRS N_2O paper was published at *J. Geophys. Res. Atmos.*, 2014 -- one candidate component for AIRS–V7

- Validation to AIRS-V6 CH_4 product – completed
  Validation of GOSAT CH_4 using AIRS-V6 CH_4 -- on-going

- L1 Requirement of Trace Gases in JPSS-1 &
  Set-up of CH_4 and N_2O retrievals in NUCAPS

- Monitoring of Arctic CH_4 emissions associated with Global Warming -- Algorithm Optimization/Improvement and Quality Control need to be done !

- Summary

JOURNAL OF GEOPHYSICAL RESEARCH
Atmospheres
AN AGU JOURNAL

JGR

Research Article

Retrieval of nitrous oxide from Atmospheric Infrared Sounder: Characterization and validation

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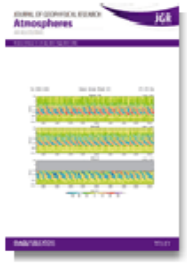
Issue



Journal of Geophysical Research: Atmospheres

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Keywords:
trace gas; satellite; remote sensing; trend

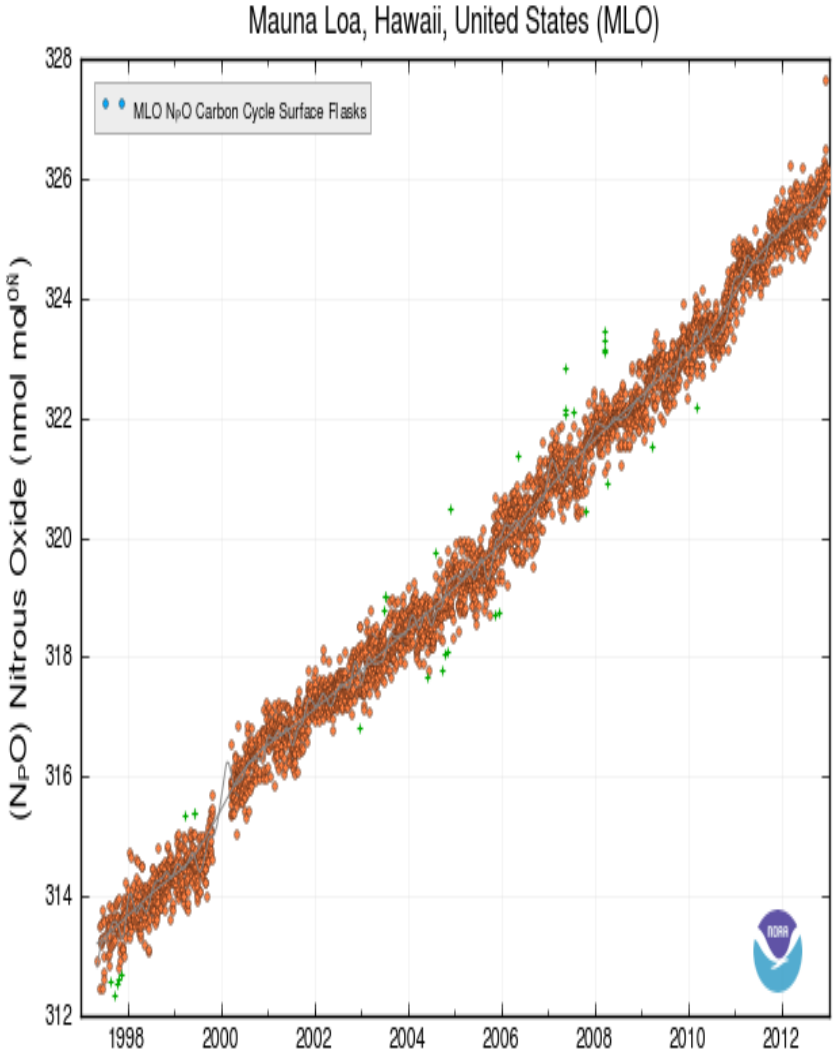
Abstract

This paper presents the retrieval algorithm of nitrous oxide (N_2O) using the Atmospheric Infrared Sounder (AIRS) on EOS/Aqua, its validation using aircraft measurements, and one possible application for monitoring the global N_2O annual trend from 2003 to 2013. The results demonstrate that AIRS is sensitive to N_2O in the middle to upper troposphere, with the peak vertical sensitivity between 200 and 750 hPa and the sensitivity in the tropics larger than in the high-latitude regions. The degrees of freedom of the N_2O retrieval are mostly between 1.0 and 1.5. Validation using the aircraft measurement profiles by the High-Performance Instrumented Airborne Platform for Environmental Research Pole-to-Pole Observations program over the Pacific Ocean indicated that the retrieval RMS error is mostly less than 8 ppb (or ~2.1%). One important feature is that the variability of N_2O from AIRS is more than 2 times than that of the aircraft measurements in the lower troposphere. In agreement with surface measurements, a modeling trend of N_2O can be obtained based

Monitor global N_2O trend

Why is it important ?

- One important greenhouse gases with a life time of 120 years,
- Warming potential is 300 times of CO_2;
- has a nearly linear increase of 0.26% yr^{-1} over the last three decades [IPCC, 2007].
- N_2O is recognized as the <u>single most important anthropogenically emitted stratospheric ozone depleting substance</u> [Ravihsankara et al., 2009].



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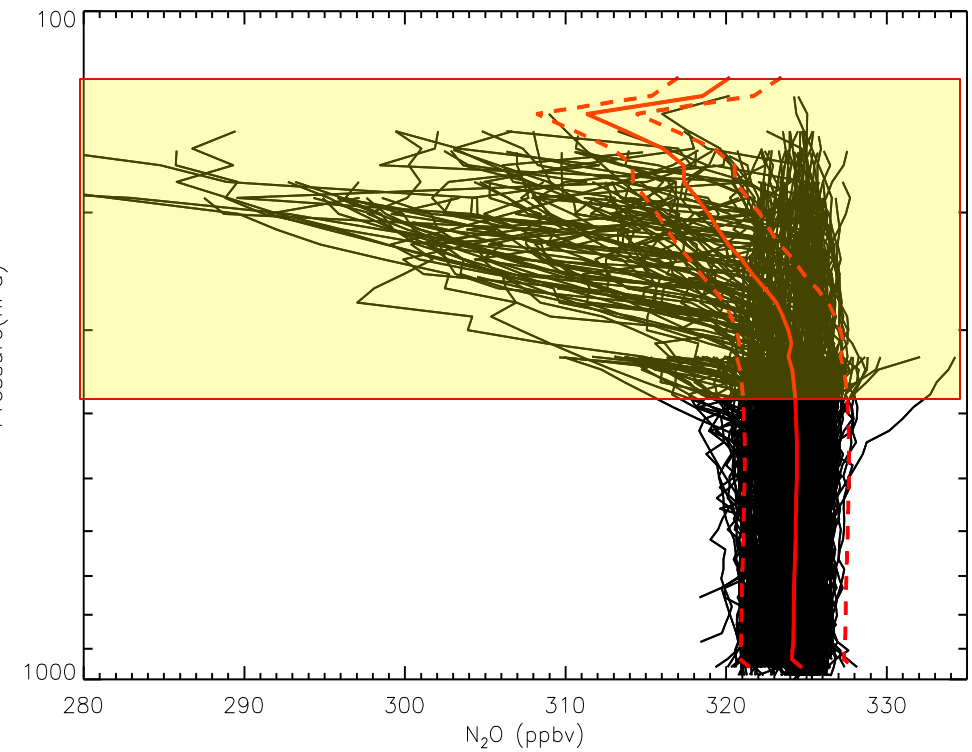
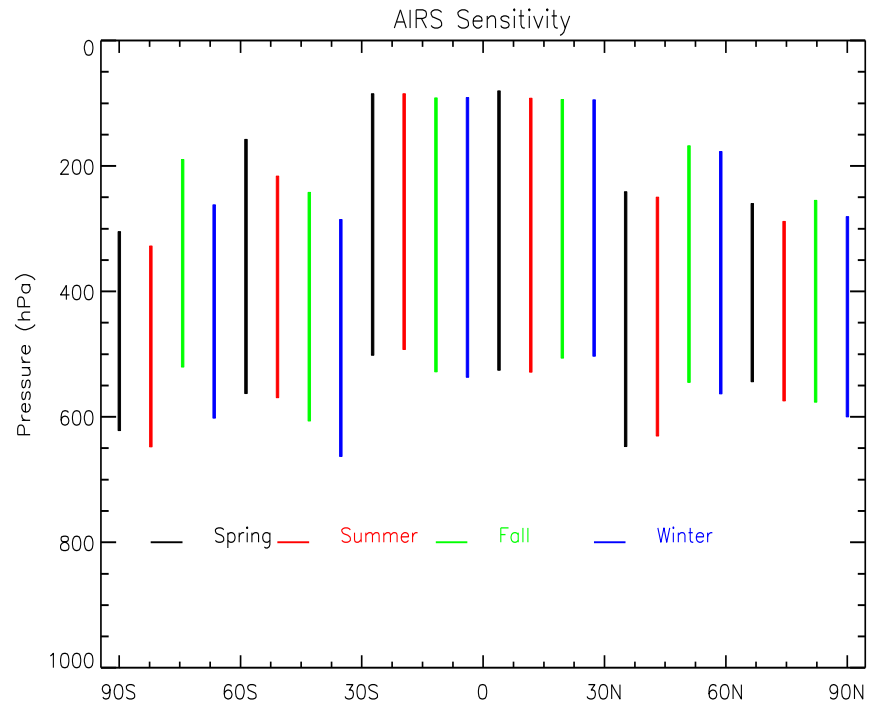
Advantage of TIR in N_2O Observation

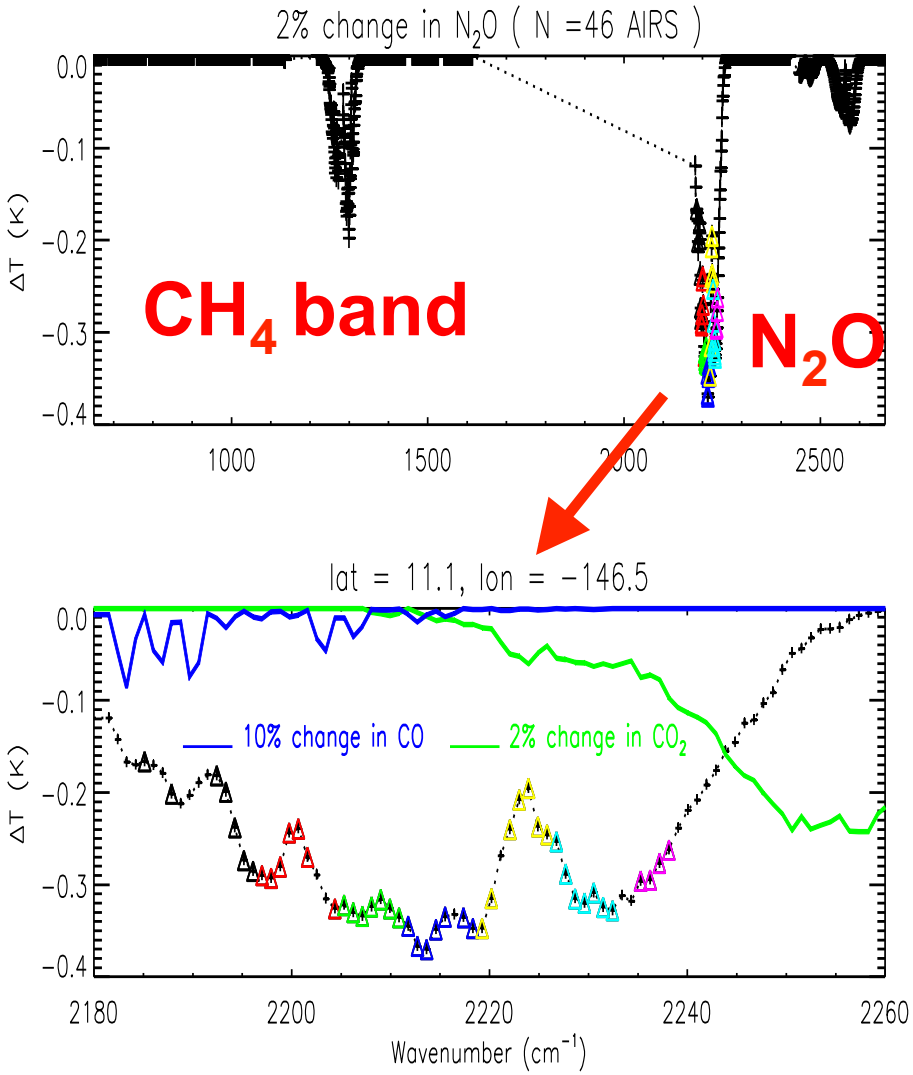




Largest variability is in the Mid-Upper troposphere from HIPPO aircraft measurements

Peak TIR Sensitivity is at Mid-Upper troposphere

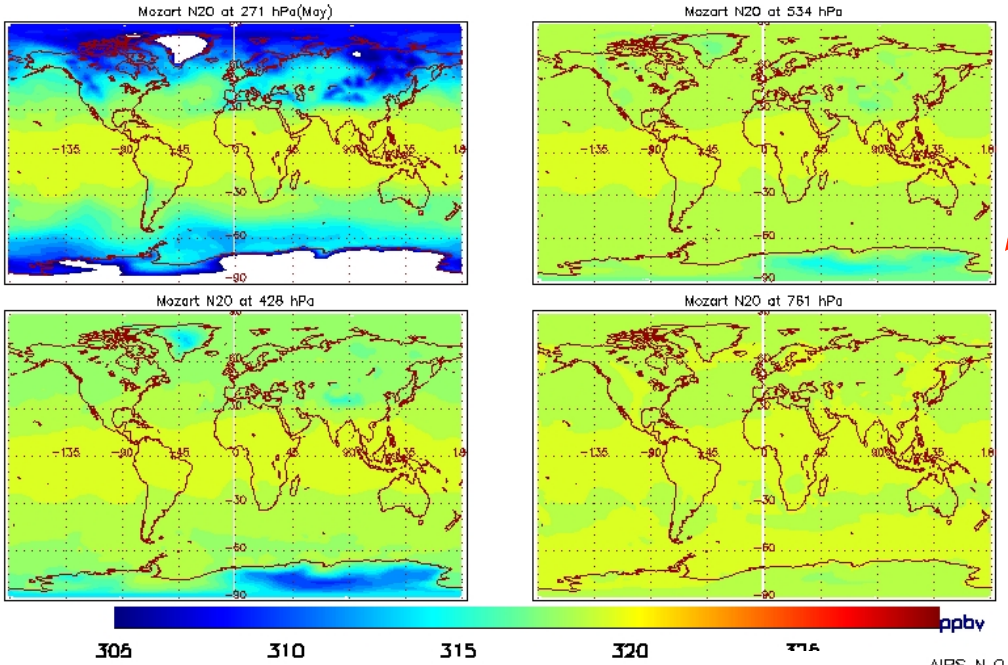
Interference between CH_4 and N_2O



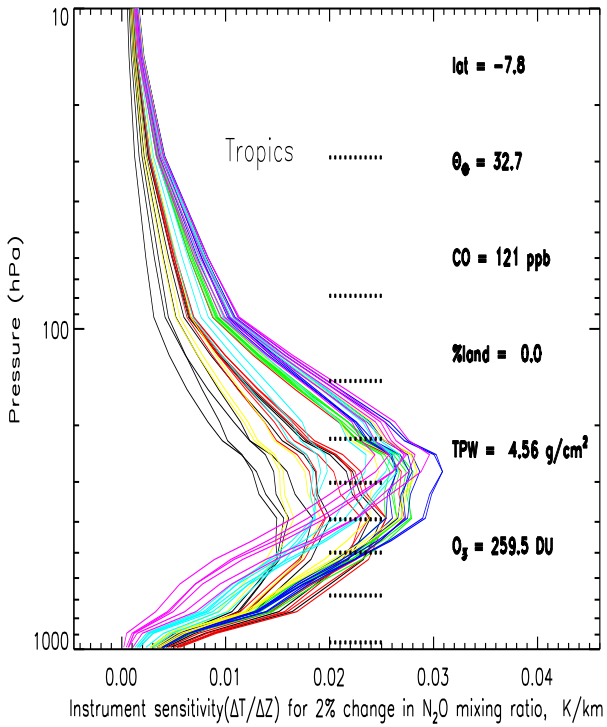
A good estimate of N_2O will improve CH_4 product, which can further improve the retrieval of water vapor;

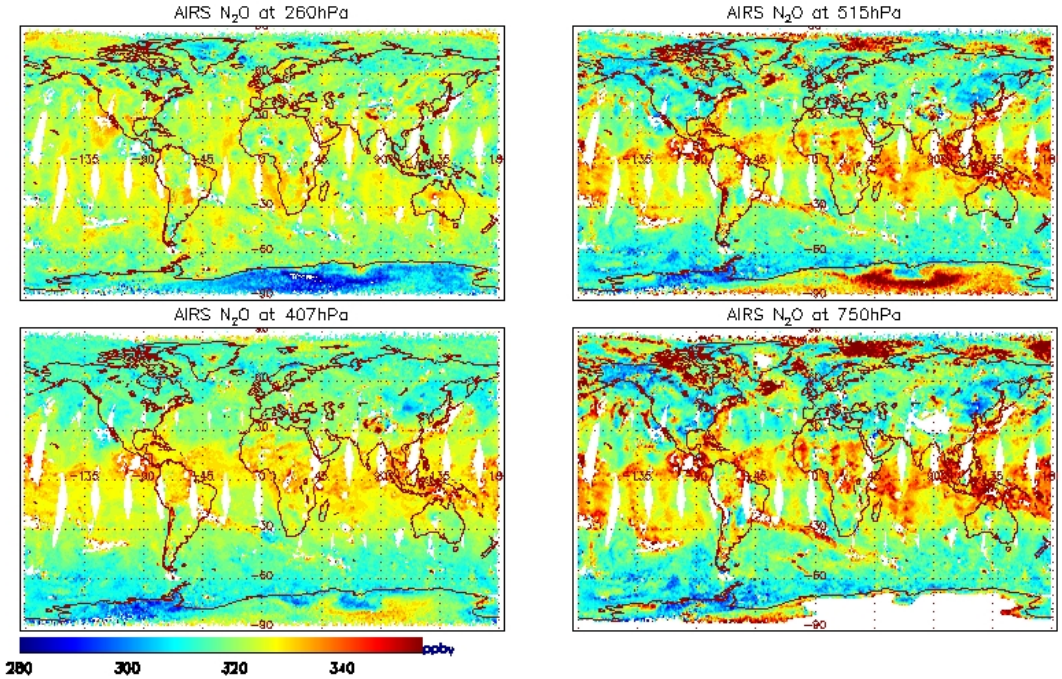
Change of BT for 2% change of N_2O

MOZART on May, 2004



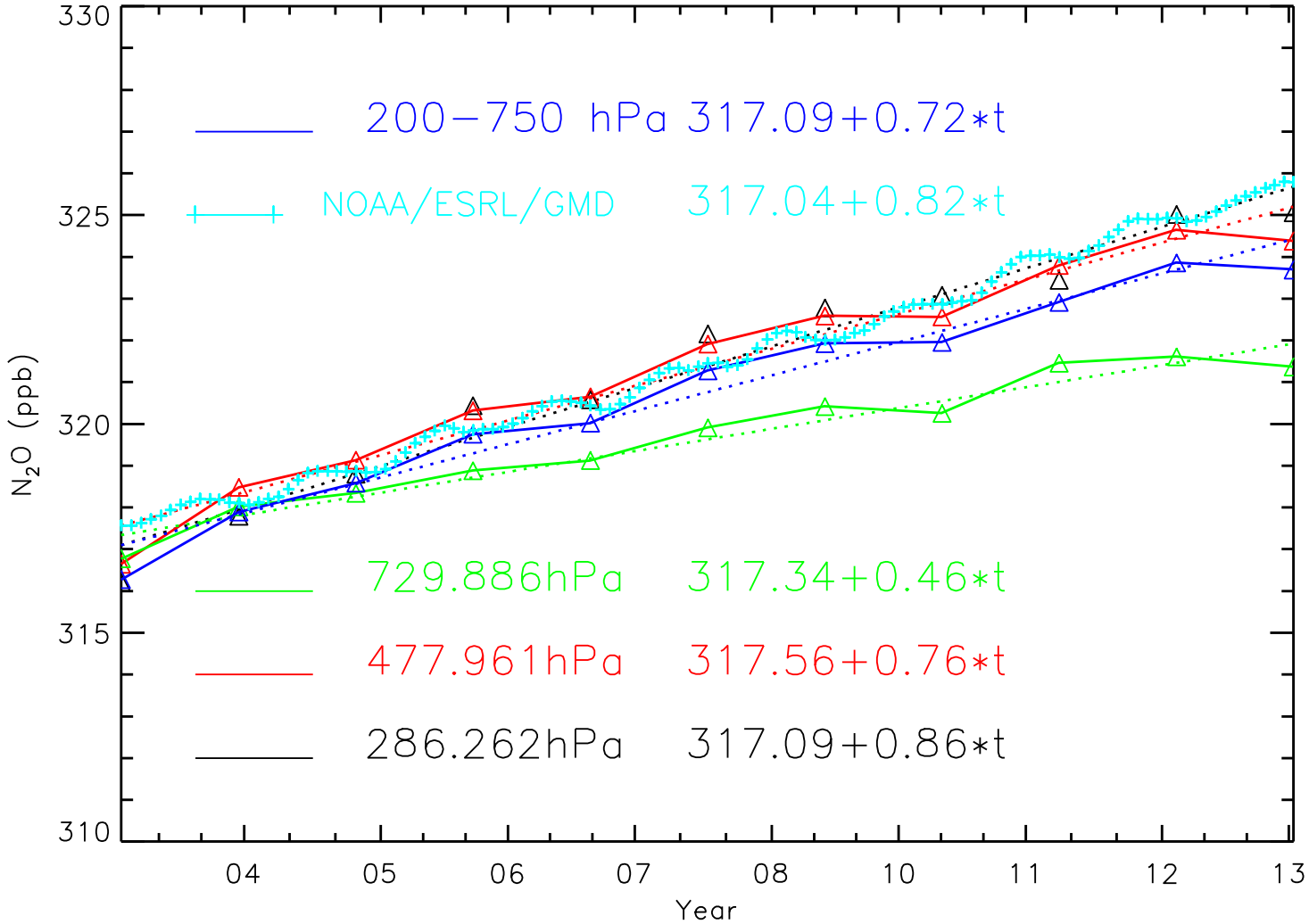
Enhancement of N_2O in the tropics





AIRS on 5/15/2012

N_2O trend from limited AIRS data



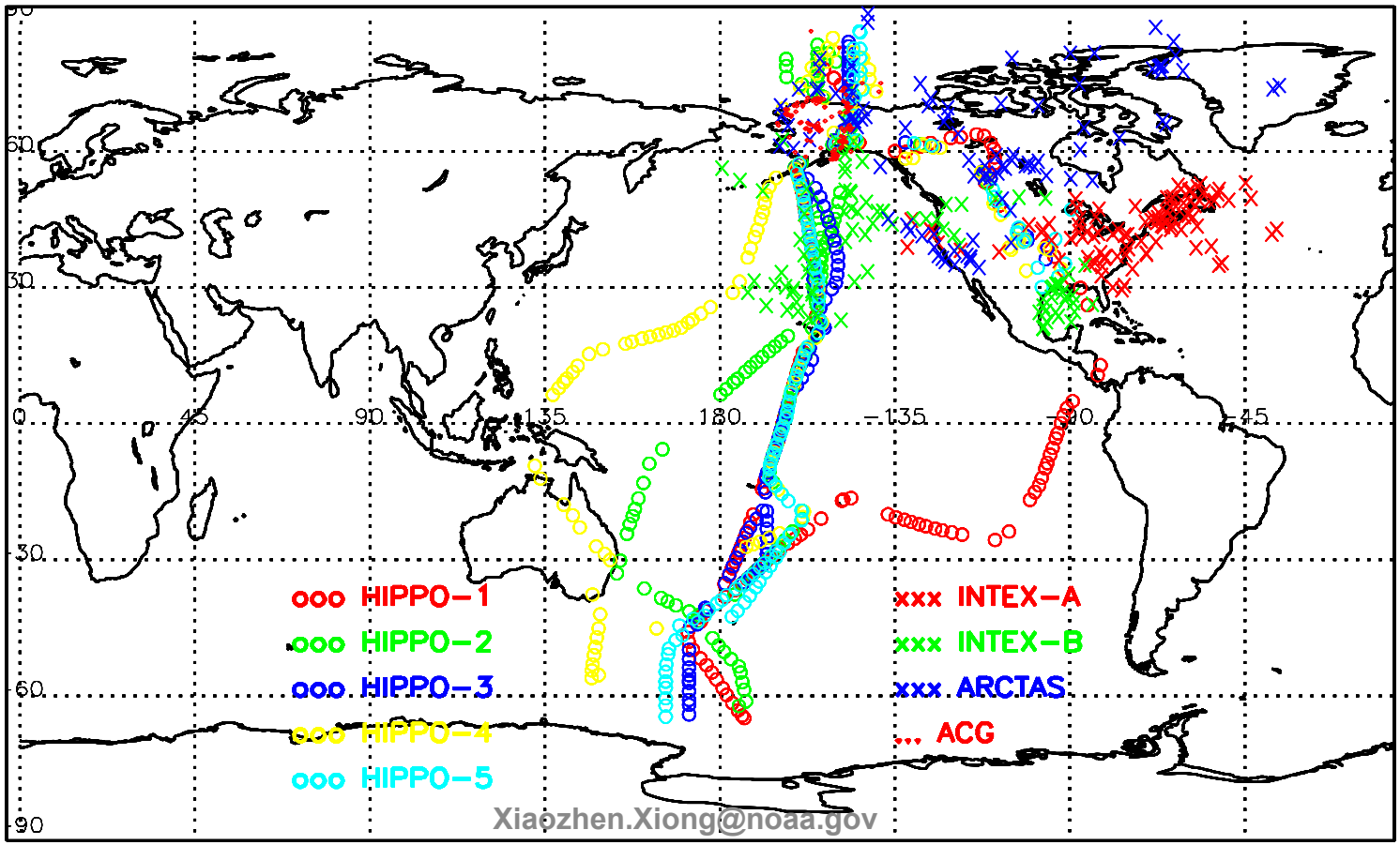
Xiong, X. et al., 2014, Retrieval of Nitrous Oxide from Atmospheric Infrared Sounder: Characterization and Validation, *J. Geophys. Res. Atmos.*, 119, doi:10.1002/2013JD021406.

Validation to AIRS-V6 CH_4

(More collaboration with science campaigns should be made.

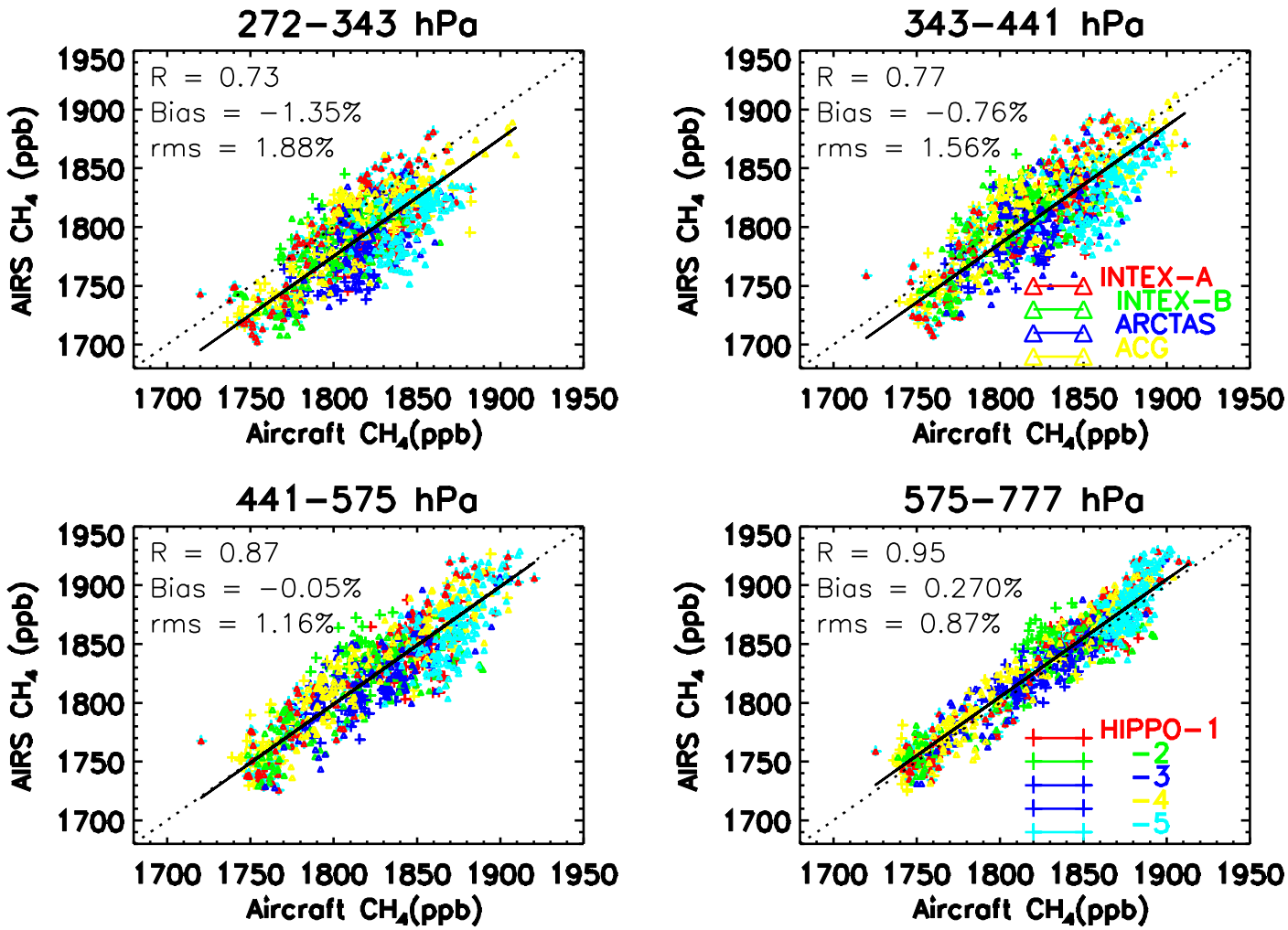
-- CrIS trace gases workshop, Sept 18-19, 2014)

Locations of Validation Profiles

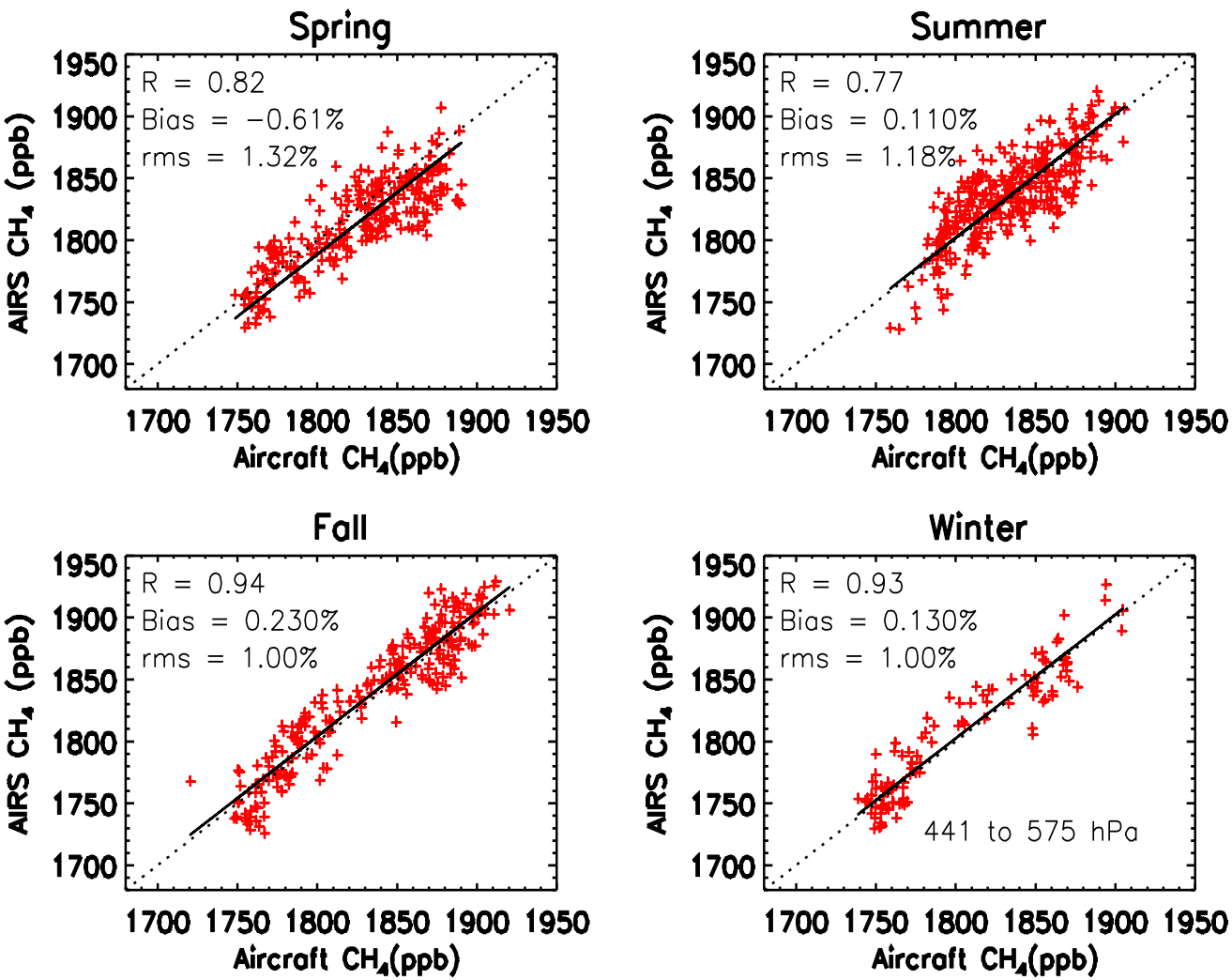


Validation Results : AIRS-V6 CH_4

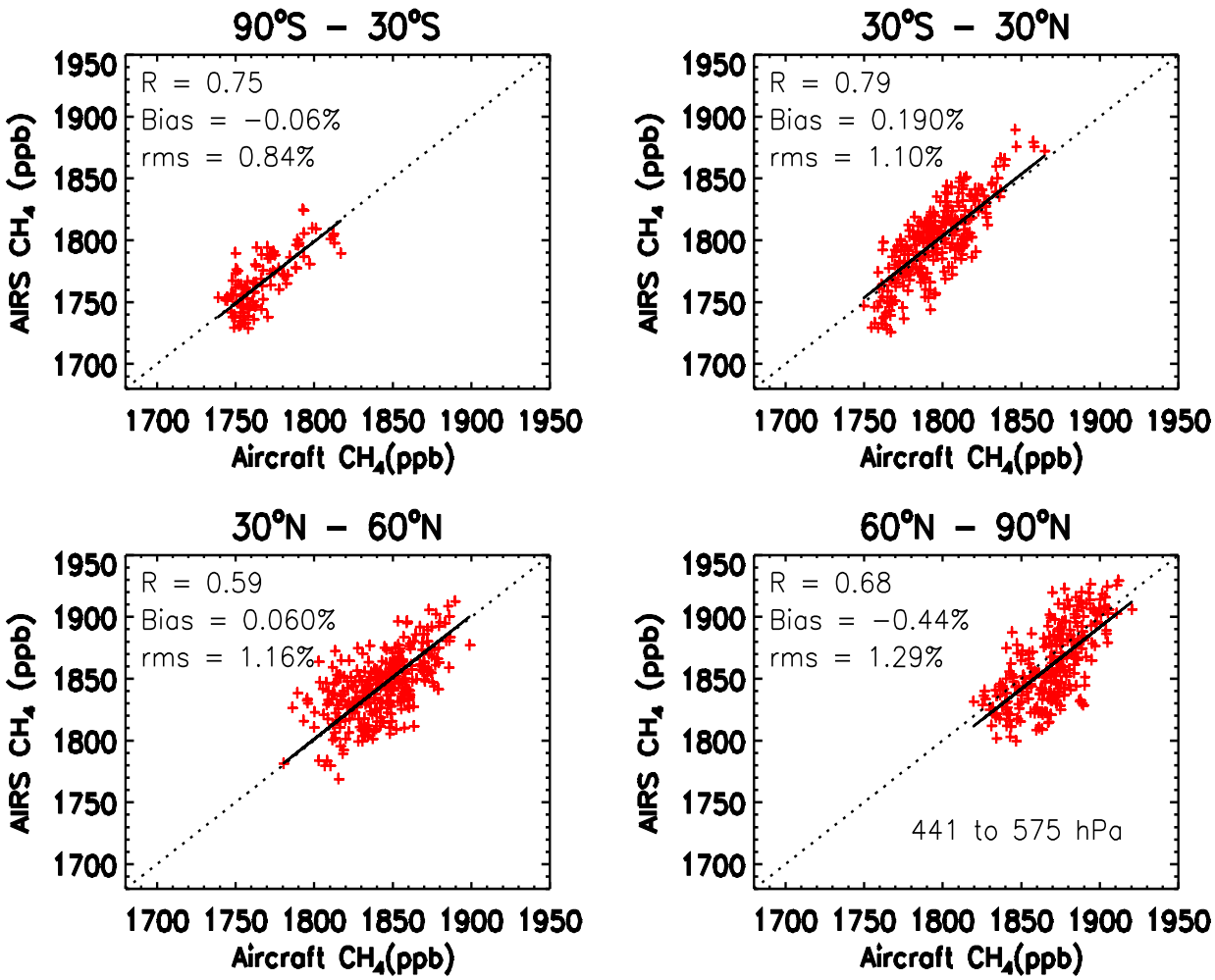
(paper is to be submitted to AMT, 2014)



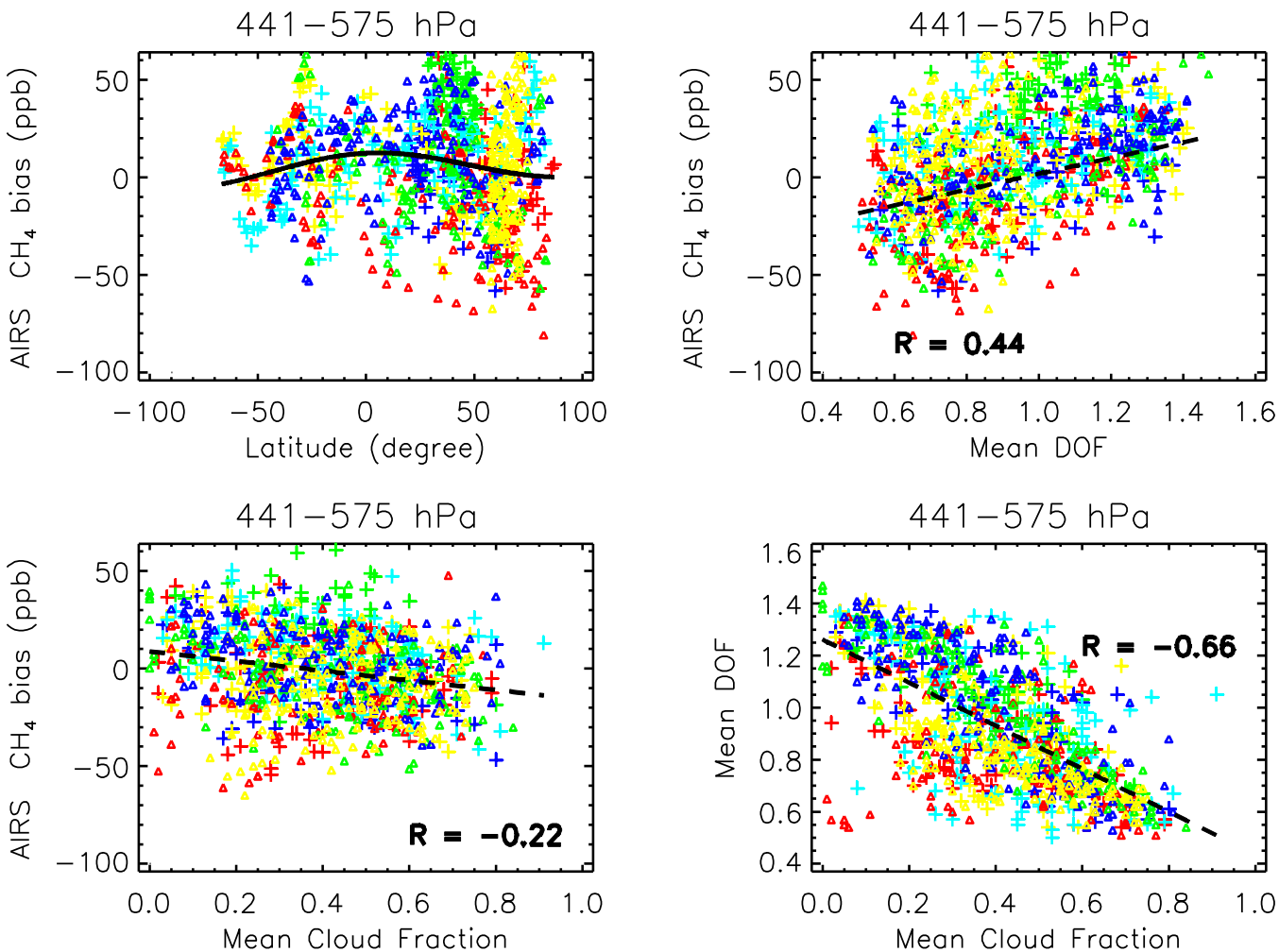
For different Seasons



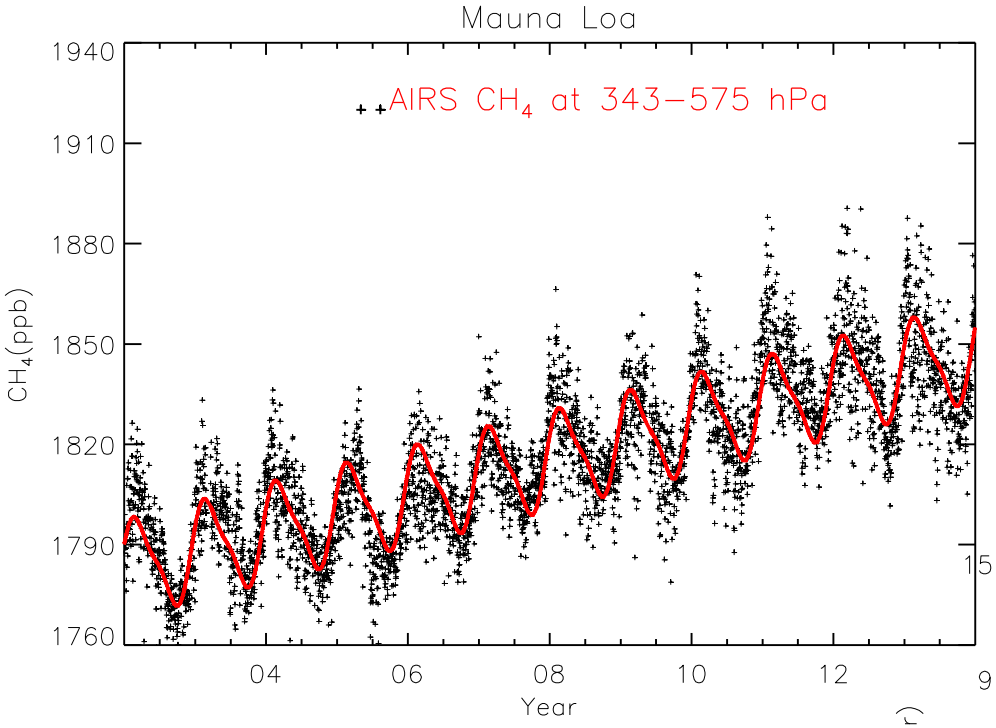
For Different Latitude zones

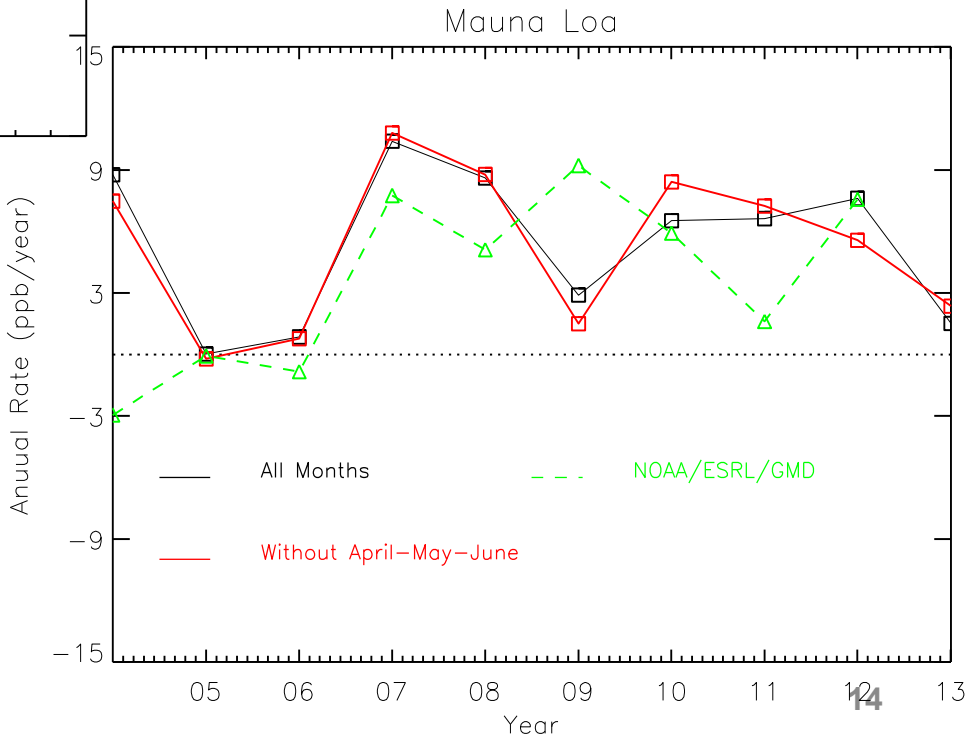


Retrieval Error vs Cloud Amount, DOF



CH_4 Trend


Mauna Loa
AIRS CH4 at 343–575 hPa
CH4(ppb)
1940
1910
1880
1850
1820
1790
1760
04
06
08
10
12
Year


Mauna Loa
Anuual Rate (ppb/year)
15
9
3
−3
−9
−15
All Months
NOAA/ESRL/GMD
Without April–May–June
05
06
07
08
09
10
11
12
13
Year

CH_4 and N_2O Retrievals from IASI

- Similar algorithm for IASI on Metop-B and Metop-A is used at NOAA CLASS;
- Validation and QC setting for IASI CH_4 on Metop-A has been done and the results were published by Xiong et al, AMT, 2013

Now let's move to CrIS on S-NPP and JPSS-1

Trace Gases Listed in JPSS-1 Requirements

EDR Attribute	CO	CO_2	CH_4
Vertical Coverage	Total Column	Total Column	Total Column
Horizontal Resolution	100 km	100 km	100 km
Mapping Uncertainty, 3 sigma	25 km	25 km	25 km
Measurement Range	0 – 200 ppbv	300 – 500 ppmv	1100 – 2250 ppbv
Measurement Precision	35%	0.5% (2 ppmv)	1% (~20 ppbv)
Measurement Accuracy	±25%	±1% (4 ppmv)	±4% (~80 ppbv)
Refresh	24 h	24 h	24 h
Note			

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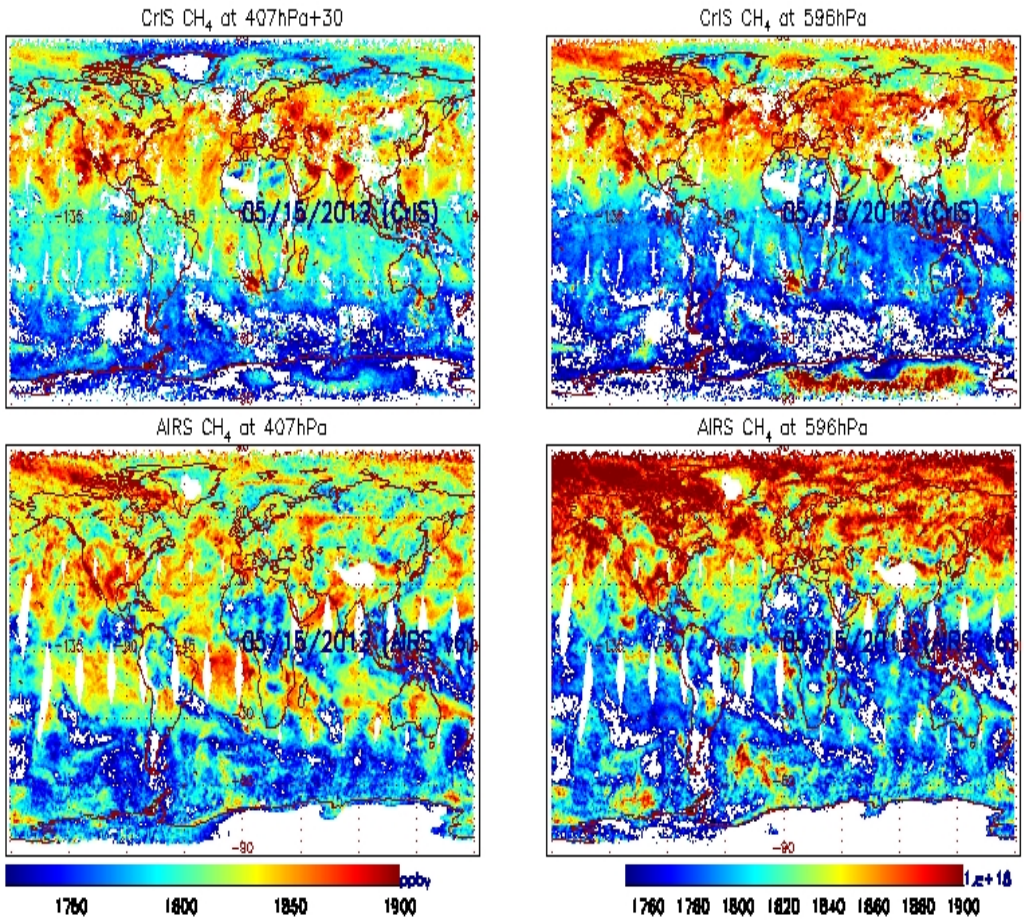
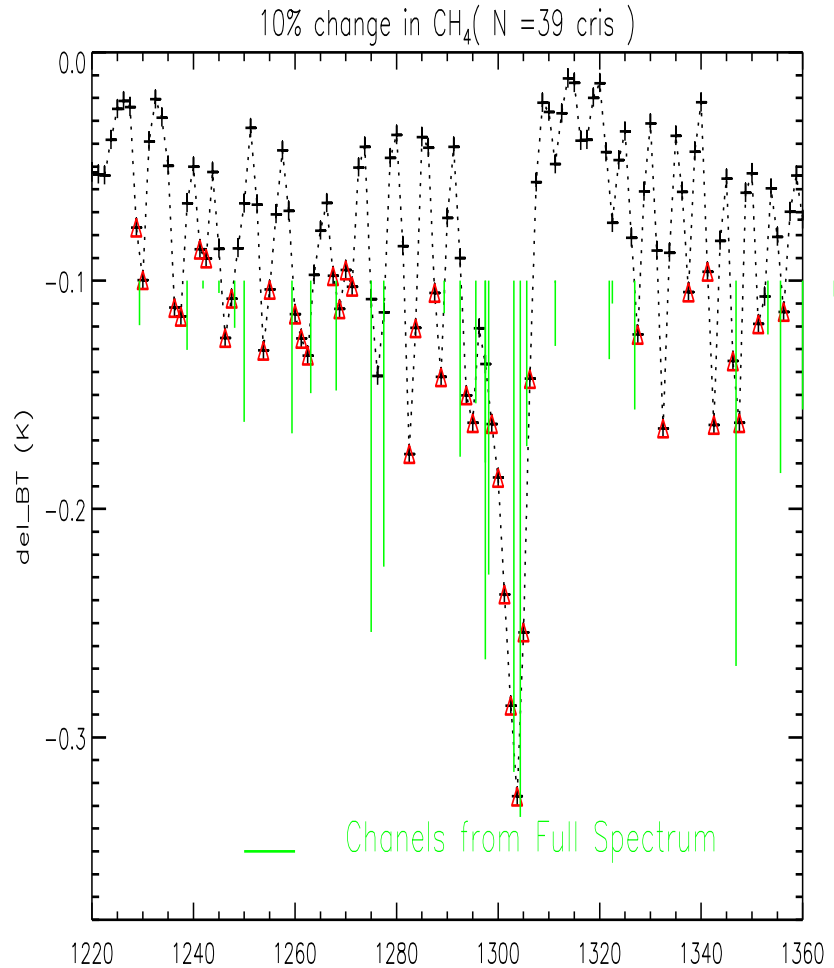
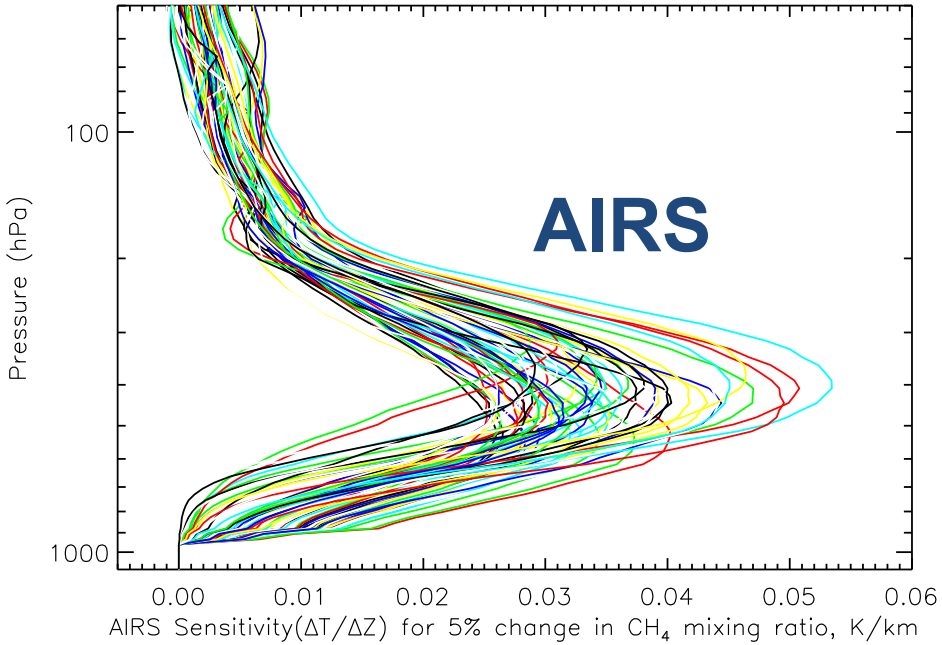
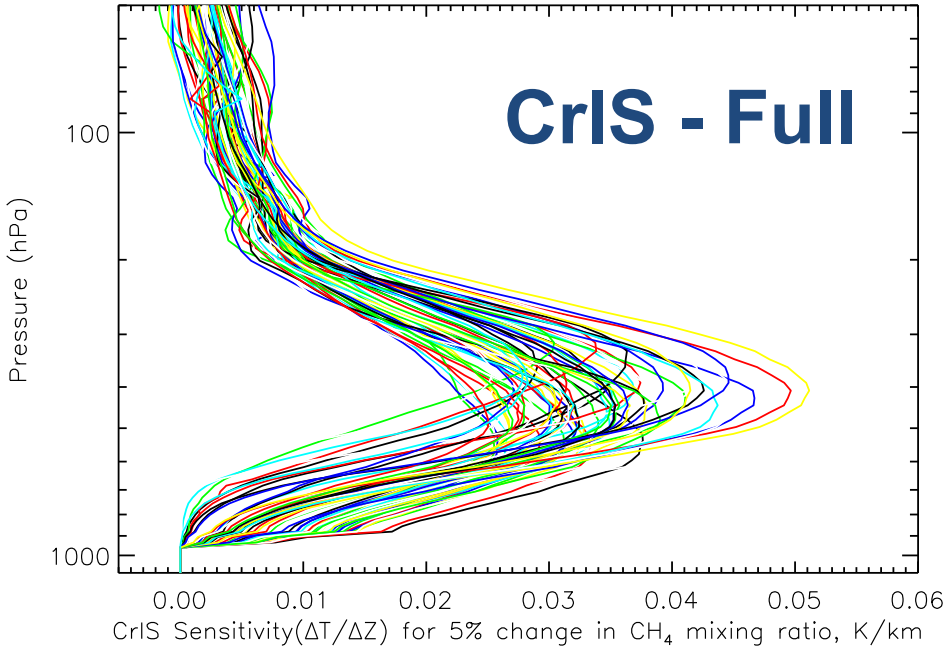
Comparison of CH_4 from CrIS and AIRS





Full spectrum CrIS data will be used soon





- **S-NPP and JPSS can be used to obtain similar N_2O and CH_4 products like AIRS and IASI**

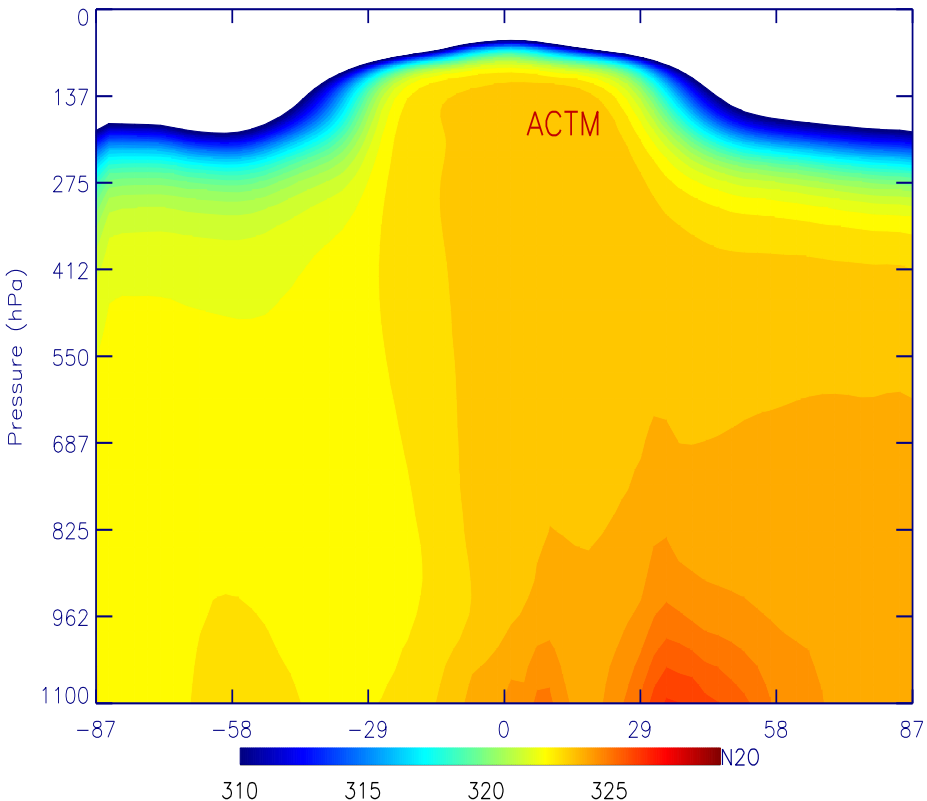
- **Full spectrum data from CrIS on S-NPP will be processed at NOAA within one month. available soon.**

- **CO_2, CO and CH_4 are listed as level-1 requirements in J-1**

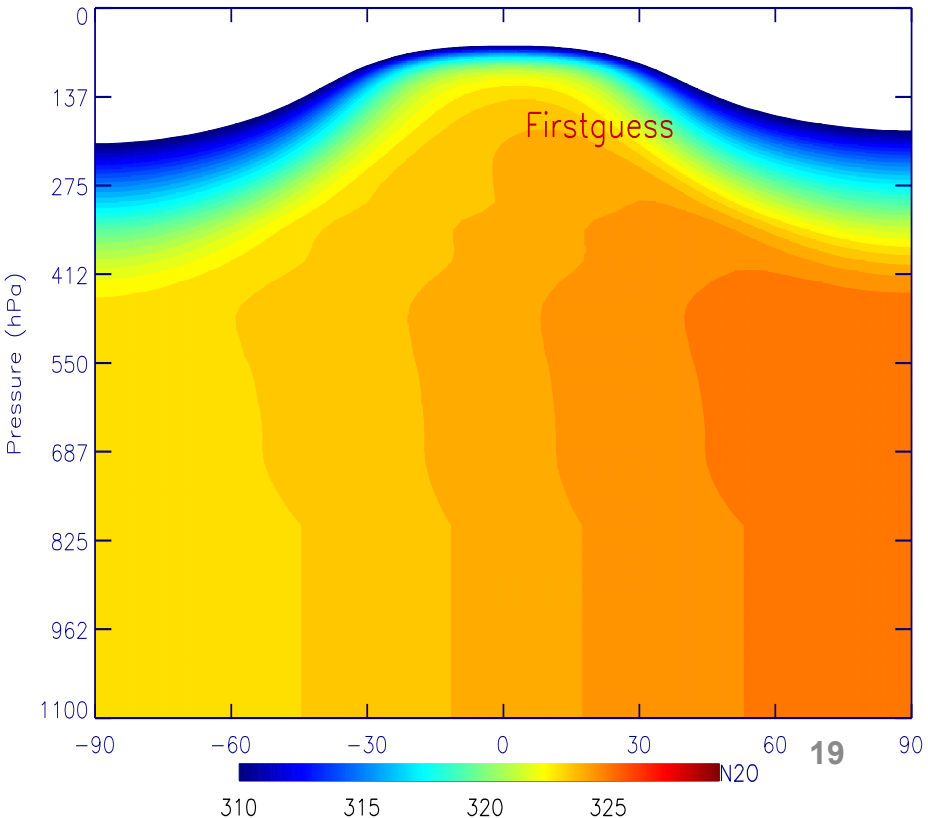
Set-up of CH_4 and N_2O Retrieval

First guess of CH_4 and N_2O is updated considering their recent increase trend

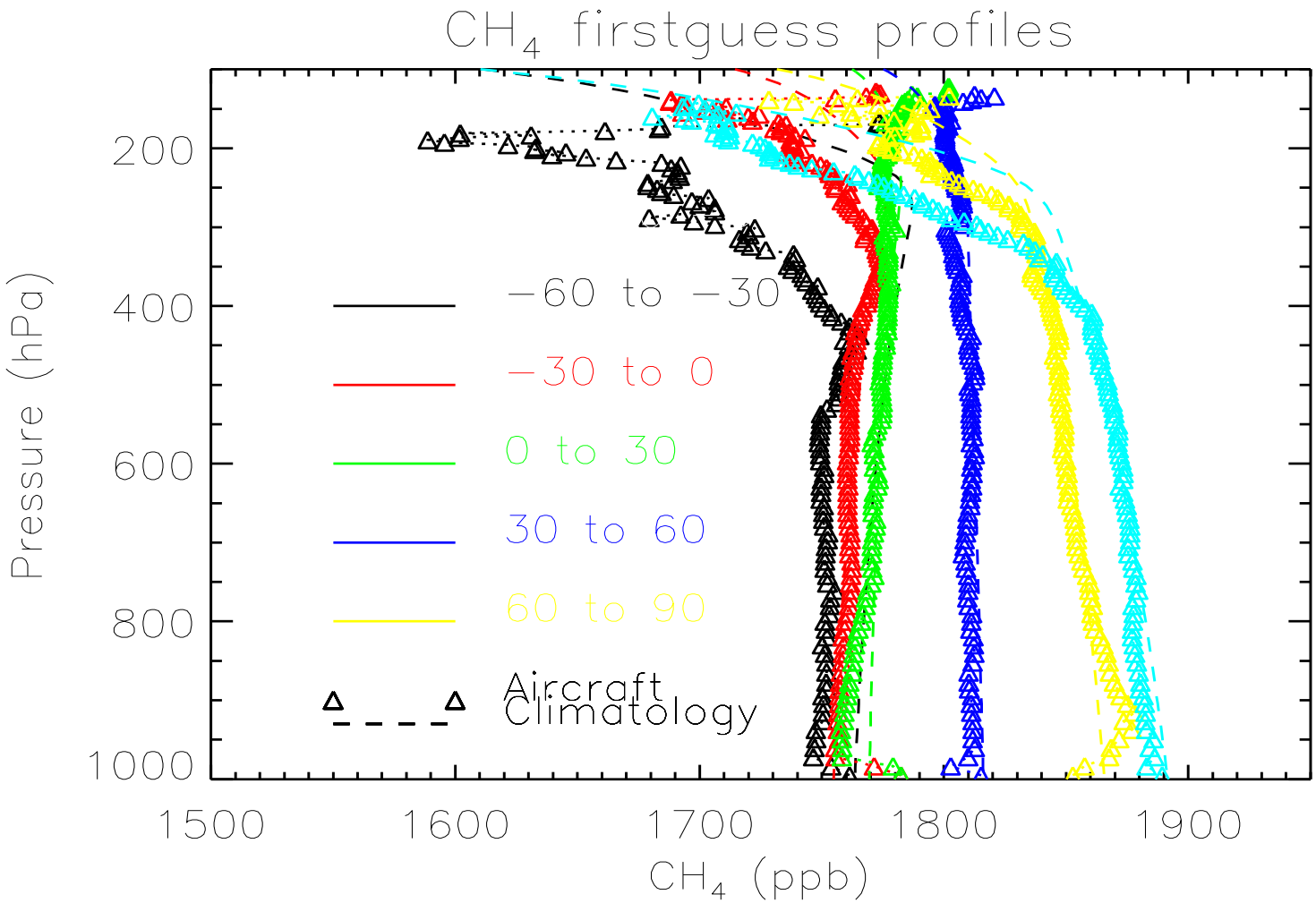
N_2O from Model



N_2O firstguess



CH_4 First-guess vs HIPPO Aircraft measurement



Monitor CH_4 emissions in the Arctic

- CH_4 emissions from thawing permafrost and/or hydrate leakage, as a positive feedback of global warming, is a big concern;

- There are more and more evidences showing its acceleration but its global impact is uncertain;

- Ground-based observation network in the Arctic is sparse;

- CH_4 remote sensing using NIR sensors (1.6 μm) is hampered by its low reflectivity over snow/ice/water surfaces and low solar angles in the Arctic;

- All seasons, day/night measurements in the Arctic are possible using AIRS, IASI and CrIS;

- Even more data are available in the polar than in other regions, due to the large swath and the over of satellite overpasses;

- So, a valuable CH_4 data record from 2002 to present over the Arctic regions can be derived using AIRS;

- overplay using current data should be careful and may misleading; As optimization and improvement to algorithm, as well as a better QC need to be done. Unfortunately, our last ROSE proposal did not go through.

Summary

AIRS provide 12 years data since 2002, and validation to AIRS-V6 CH_4 has been completed;

Continued measurement will be made using CrIS on S-NPP and J-1, -2, as well as IASI;

It is promising to monitor the trend of N_2O in the mid-upper troposphere. Moreover, a good retrieval of N_2O will improve the CH_4 and H_2O retrievals → it is recommended to add N_2O retrieval in AIRS-V7;

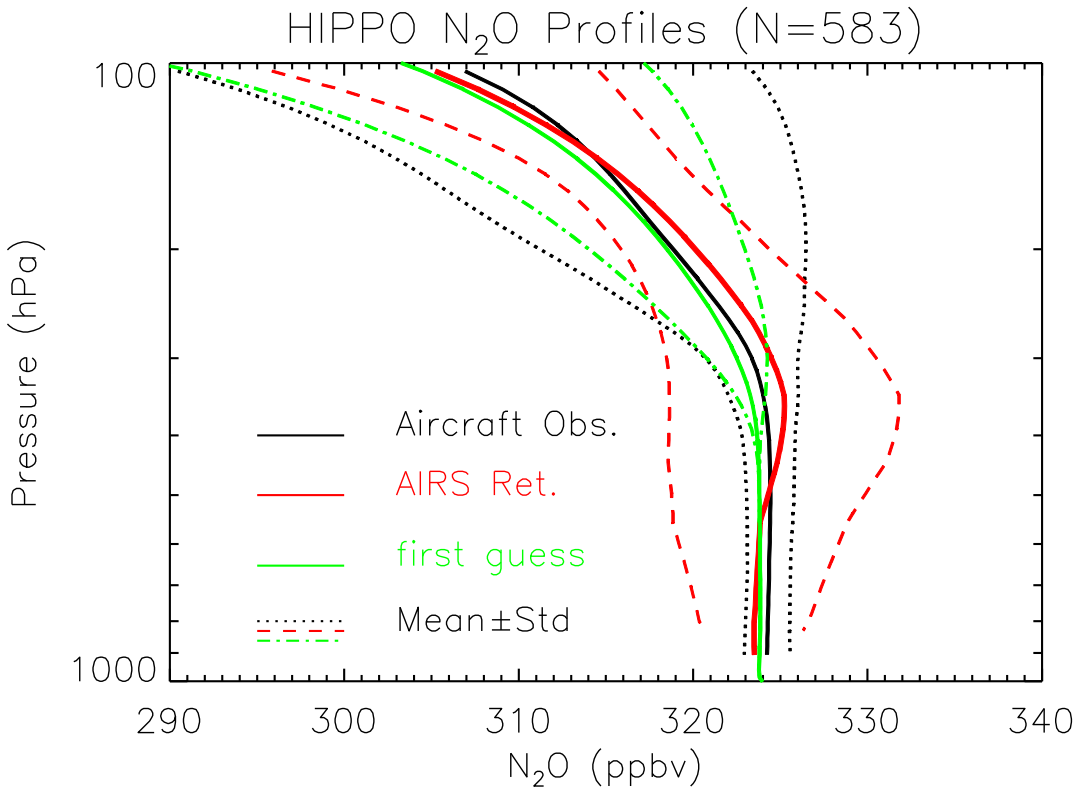
A valuable long-term measurement of CH_4 over the Arctic regions is possible using TIR, but need additional funding support as it is not an operational product and cannot be simply derived from current product.

Questions/Suggestions

List of publications

1. **Xiong, X.** et al., 2014, Retrieval of Nitrous Oxide from Atmospheric Infrared Sounder: Characterization and Validation, JGR-atmosphere.
2. **Xiong, X.** , Barnet, C. D., Maddy, E., et al., 2013, Detection of Methane Depletion Associated with Stratospheric Intrusion by Atmospheric Infrared Sounder (AIRS), GEOPHYSICAL RESEARCH LETTERS, VOL. 40, Issue 10, Pages: 2455–2459, doi:10.1002/grl.50476, 2013.
3. **Xiong, X. et al.**, 2013, Mid-Upper Tropospheric Methane Retrieval from *IASI* and its Validation, Atmos. Meas. Tech. , 6, 2255-2265, doi:10.5194/amt-6-2255-2013, 2013.
4. **Xiong, X**., Barnet, C.D., Maddy, E., Liu, X., and Goldberg, M., 2012. Atmospheric Methane in the High Northern Hemisphere and its Relation with Permafrost . *Proceedings of the Tenth International Conference on Permafrost*, Russia: 1981-1986 pp, 2012.
5. **Xiong, X.,** Barnet, C. D., Maddy, E. , Wei, J., Liu, X., Thomas.S.Pagano, 2010, Seven Years' Observation of Mid-Upper Tropospheric Methane from Atmospheric Infrared Sounder, *Remote Sensing* **2010**, *2*, 2509-2530; doi:10.3390/rs2112509.
6. **Xiong, X**., Barnet, C.; Zhuang, Q.; Machida, T.; Sweeney, C.; Patra, P.K., 2010,Mid-upper Tropospheric Methane in the High Northern Hemisphere: Space-borne Observations by AIRS, Aircraft Measurements and Model Simulations, *J. Geophys. Res*., 115, D19309, doi:10.1029/2009JD013796.
7. **Xiong, X.,** Barnet, C., Wei, J., and Maddy, E.: Information-based mid-upper tropospheric methane derived from Atmospheric Infrared Sounder (AIRS) and its validation, Atmos. Chem. Phys. Discuss., 9, 16331-16360, 2009.
8. **Xiong, X**., S. Houweling, J. Wei, E. Maddy, F. Sun, C. D. Barnet, 2009, Methane Plume over South Asia during the Monsoon Season: Satellite Observation and Model Simulation, Atmos. Chem. Phys., 9, 783-794, 2009.
9. **Xiong**, X., Barnet, C.D., Maddy, E., Liu, X., and Goldberg, M., 2008. Variation of Atmospheric Methane over **the Permafrost Regions** from Satellite Observation during 2003 to 2007. *Proceedings of the Ninth International Conference on Permafrost*, Alaska, USA: 1981-1986 pp,2008.

A larger variation of N_2O in the mid-upper troposphere from AIRS than aircraft measurment



Xiong et al., JGR-atmosphere, 2014

NUCAPS Sounding Products Released at NOAA CLASS since April 8, 2014

- Atmospheric Vertical Temperature Profile
- Atmospheric Vertical Moisture Profile
- Infrared Ozone Profile

- (requirement: total column)
- Vertical CO Profile
- Vertical CO_2 Profile
- Vertical CH_4 Profile
- Outgoing Longwave Radiation (OLR)

- (new)
- Vertical HNO_3 Profile
- Vertical N_2O Profile
- Vertical SO_2 Profile
- A flag indicating the presence of dust and volcanic emissions
- Cloud-Cleared Radiances